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CONCEPTUAL SITE MODEL
HUSTER ROAD SUBSTATION
3800 HUSTER ROAD
ST. CHARLES, MISSOURI

by
Haley & Aldrich, Inc.
Manchester, New Hampshire

for
Ameren
St. Louis, Missouri

File No. 0201590-000
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File No. 0201590-000

Ameren Missouri Environmental Services
One Ameren Plaza
St. Louis, Missouri 63103

Attention: Barbara Miller

Subject: Huster Road Substation
3800 Huster Road
St. Charles, Missouri

Dear Barbara Miller,

This Conceptual Site Model (CSM) was prepared on behalf of Ameren Missouri (Ameren) by Haley & Aldrich, Inc, (Haley & Aldrich) for the Huster Electrical Power Substation located at 3800 Huster Road, in St. Charles, Missouri (the Site). The CSM evaluates the potential for the City of St. Charles' (City's) municipal groundwater extraction well CW-10 to capture chlorinated volatile organic compounds (CVOCs) related to the Site following a shut-down of the Site Groundwater Extraction and Treatment System (GETS). The CSM is based on a groundwater flow, fate, and transport numerical model. Model results indicate the following:

- CVOCs from the Site would not reach CW-10 during anticipated and normal operation of the Elm Point wellfield;
- A theoretical potential for capture exists only in extreme, unanticipated operating conditions and even then, modelling indicates that Site-related CVOCs would take at least 400 days to reach CW-10 and would likely be diluted below detection limits in the produced water.

General Site Information

The Huster Electrical Power Substation is an active substation located at 3800 Huster Road in St. Charles, Missouri. The Substation, which was first developed in 1963, is an approximately 4-acre parcel located about 500 feet (ft) south of Route 370 (Figure 1). The Substation is protected by a 12-ft high levee that was constructed in 1994 due to flooding of the Mississippi River.

The Hayford Bridge Road (HBR) Superfund Site was established in the 1980s to address soil and groundwater contamination related to industrial recycling of chemicals at the Findett property, located approximately one half mile to the south-southeast of the Substation. The original HBR Site is composed of three Operable Units: OU1, OU2 and OU3 which address soil and groundwater impacted by several chemical constituents including polychlorinated biphenyls and chlorinated volatile organic compounds

(CVOCs). Soil impacted by CVOCs beneath the Substation and an associated groundwater plume were added to the HBR Superfund Site as Operable Unit 4 (OU4) in 2011 (USEPA, 2020). CVOCs in OU4 have been related to historical use of chlorinated solvents to clean equipment at the Substation and not related to activities at the Findett property.

The Substation is situated in the midst of the Elm Point Wellfield, which is used as a source of potable water for the City of St. Charles. The Elm Point Wellfield currently has five active wells (CW-6, CW-7, CW-8, CW-9 and CW-10 on Figure 1). Inclusion of the Substation in the larger Findett Superfund Site is due to the proximity of both areas to these wells. The USEPA Record of Decision (ROD) issued in 2005 for OU3 also contains provisions for protecting this water supply. These include monitoring the influent stream at the City of St. Charles' water treatment plant, installation of aeration equipment at the water treatment plant to remove CVOCs, and institutional controls "to ensure that no drinking water wells would be installed in the OU3 contaminated aquifer." (USEPA, 2020).

Aquifer Characteristics

The Substation is situated above the Mississippi River Alluvial Aquifer, a 100 to 150 foot thick sequence of sands and gravels (Miller et al., 1974). During the Pleistocene, the ancestral Mississippi and Missouri Rivers incised into Paleozoic bedrock, depositing this sequence of coarse-grained sediments. These were subsequently covered by fine-grained floodplain deposits, creating a semi-confining layer of silts and clays (Figure 2).

The alluvial aquifer is recharged from the bedrock subcrop to the South, from infiltrating precipitation, and stream water infiltration (Miller et al., 1974). Depending on stage, the alluvial aquifer either recharges from or discharges to the Mississippi river. Additionally, the Mississippi river floodplain is frequently inundated by several feet of water during major flooding events in this area. Groundwater flows generally towards the river during low stage, away from the river during high stage, and likely in some phase of transition while inundating floodwaters are rising and receding. This makes prevailing natural groundwater flow directions ambiguous, as they likely vary between wetter and dryer periods. In the general area of the Site, there are no observations of truly natural conditions as groundwater elevations have been strongly influenced by groundwater extraction for at least the past 50 years. The potentiometric contours published in Miller et al. (1974) show a +5 foot groundwater depression in this area (Figure 3). Since the original five wells of the Elm Point wellfield had been in operation since at least 1969 (e.g., Geotechnology, 2005) the depression observed in 1974 was likely the result of municipal groundwater extraction similar to that taking place today. A northward groundwater flow direction may be more persistent near the edge of the bedrock subcrop where lateral underflow recharge from higher elevations creates a more consistent gradient. Miller et al (1974) reported that this "valley wall" recharge may account for as much as 3.29 million gallons per day per mile and will increase as a function of increased pumping from the alluvial aquifer. In this conceptual framework, groundwater flow in the OU3 area is likely to be driven more strongly by the lateral bedrock underflow than at the Site and in the OU4 area.

Miller et al. (1974) reported a test of the alluvial aquifer at an unspecified location that yielded a transmissivity of 36,180 ft^3/day/ft and storativity of 0.0004. The low storativity value indicates a confined or semi-confined aquifer. This transmissivity equates to a hydraulic conductivity 362 to 452 ft/day for an average aquifer thickness of 80 to 100 feet. In a feasibility study for a future high capacity well, multi-stage and constant rate pumping tests were performed in municipal well CW-7 with water levels monitored in a network of temporary piezometers (International Water Consultants, 2002). These tests resulted in an estimated transmissivity of 200,000 gallons/day/ft and a storativity of 0.006. For the saturated thickness value assumed in the study (69 feet), this equates to a conductivity of 387 ft/day. Per e-mail correspondence, this is the value preferred by the City for their groundwater management activities, with a low storativity that is representative of a confined or semi-confined aquifer.

The OU3 Remedial Investigation and Feasibility Study (RIFS) contains a description of a pumping test performed following the installation of CW-9. In this test, CW-9 was pumped at stepped rates up to 5,517 GPM followed by a 72-hour constant rate test at 4,252 GPM. Water levels were monitored in CW-6, CW-7 and a nearby irrigation well (Geotechnology, 2005). The resulting hydraulic conductivities are reported to be 810 – 1,085 ft/day, more than two times the conductivity determined for that same location in the 2002 feasibility study. However, the RIFS states that the data were evaluated by "restricting the aquifer thickness to the length of the screened interval in well [C]W-6." Using screen length instead of the actual aquifer thickness to convert aquifer transmissivity to hydraulic conductivity is the likely source of this discrepancy, as CW-6 is only screened across a fraction of the aquifer.

To support design of the GETS at the Site, a pumping test of the upper portion of the alluvial aquifer was conducted in an existing monitoring well and two temporary piezometers (GSI, 2013). The test resulted in estimated hydraulic conductivity values of 303, 309 and 383 ft/day with some indication that hydraulic conductivity may increase with depth. Storativity was calculated to be 0.00033 to 0.00556, indicating a confined or semi-confined aquifer.

Municipal Groundwater Wells

The City of St. Charles obtains potable water from the alluvial aquifer in the Elm Point wellfield, supplemented by treated water purchased from the City of St. Louis Public Water Supply (City of St. Charles, 2020; Missouri DNR, 2021). Groundwater extraction from the Elm Point wellfield began prior to 1969 when wells CW-4 and CW-5 were installed to supplement three wells of unknown age. Well CW-6 was installed in 1977, CW-7 in 1988 and CW-8 in 1998 (Geotechnology, 2005). The high-capacity radial collector well CW-9 was installed in 2005, and the supplemental well CW-10 was installed circa 2015-2016. The three original wells were removed from service in 1987-1988. Wells CW-4 and CW-5 are no longer used; however, it is unknown if they have been decommissioned or removed as they are still listed in the 2020 municipal water consumer confidence report (City of St. Charles, 2020). As of this report, CW-6, CW-7, CW-8, CW-9 and CW-10 (shown on Figure 1) are in regular use for water production.

Most of the modern municipal wells were installed vertically and designed to produce up to 2 MGPD, with the exception of CW-9 which was designed to produce up to 5 MGPD, and is composed of four 200-

foot long lateral wells positioned near the base of the alluvial aquifer and arranged in a radial pattern (Layne, 2020).

Extraction from the municipal wells varies with demand from the St Charles Public Water Supply (PWS) treatment plant. This demand varies seasonally, with greater water production taking place in summer months. The PWS treatment plant has a design capacity of 6 MGPD, with excess demand met by purchasing treated water from the City of St. Louis. As of 2020 the annual daily production was reported to be 4.1 MGPD (Missouri DNR, 2021). Groundwater extraction is rotated among the individual wells to avoid excessive drawdown in any one location. The OU3 RIFS included statistics of production data for January to June 2004. Except for one high-demand day during that period, the wells were operated in pairs extracting 2.5 to 3.0 MGPD, equating to approximately 900 to 1,000 gallons per minute (GPM) per well if production were distributed evenly.

To support this CSM study, data for 2020 individual monthly well rates have been provided by the City of St. Charles (Table 1):

TABLE 1
Monthly Well Rates for the Elm Point Wellfield

Well	CW-6 MGAL	CW-7 MGAL	CW-8 MGAL	CW-9 MGAL	CW-10 MGAL	Average MGPD
January	0	9.3	9.3	29.4	38.7	2.8
February	0	24.2	29	4.8	29	3.0
March	0	0	44.1	44.1	26.6	3.7
April	0	0	41.3	41.3	0	2.8
May	0	20.9	38	58.9	0	3.8
June	0	11.5	54.6	28	35.2	4.3
July	0	0	55	55	55	5.3
August	41.3	0	47	47	47	5.9
September	0	0	55.4	55.4	55.4	5.5
October	34	15	37	37	34	5.1
November	0	0	42	42	20	3.5
December	19	19	40	40	40	5.1
2020 Total	**94.3**	**99.9**	**429.7**	**482.9**	**380.9**	**4.2**

Notes: MGAL = million gallons; Average MGPD = average total daily production for all wells in millions of gallons per day.

According to these data, the majority of production appears to be evenly distributed between CW-8, CW-9 and CW-10 for most months, despite CW-9 having a much higher design capacity than the other two wells. CW-9 was re-developed in February 2020, having deteriorated from its 2005 measured specific capacity of 148 gallons per minute per foot drawdown (GPM/foot) to 27 GPM/foot, an 82% loss (Layne, 2020). This is typical of high-capacity extraction wells which degrade as the high entry velocity of groundwater causes erosion of well screens, drawing in sand and other aquifer solids. The re-development increased the specific capacity to 68 GPM/foot, still less than 50% of the original. From the redevelopment report and the rates reported for 2020, it appears that CW-9 may now have a maximum rate of approximately 2,000 GPM.

Conceptual Site Model

The Conceptual Site Model (CSM) is illustrated in Figure 4. Originally, the narrow OU4 CVOC groundwater plume formed in the upper part of the aquifer as groundwater extraction from CW-6, CW-7 and high-capacity extraction at CW-9 drew groundwater northward from beneath the Site. A set of vertical groundwater profiles from ground surface to bedrock confirmed that the plume was mostly contained within the upper 20-30 feet of the aquifer (GSI, 2013). As part of its remedial efforts, Ameren treated this groundwater plume with a combination of in-situ chemical oxidation (ISCO) injections and permeable reactive barriers (PRBs). The on-Site plume source was treated with ISCO injections and bio-augmentation while any further release was captured by pumping from the GETS extraction wells. A more comprehensive description of OU4 remediation activities may be found in the Remedial Investigation Report (Ameren, 2018). Presently, a small, localized area of CVOC impacts remains in the silt and clay and feeds a small residual groundwater plume in the uppermost aquifer that is contained by the GWCS. Ameren periodically treats the silt and clay “residual source zone with a biological amendment into the existing wells to promote microbial dechlorination of the remaining CVOCs.

Installation of CW-10 in 2015-2016 has added an additional pumping stress to the east of the Site and roughly perpendicular to the strong northward groundwater flow created by pumping from CW-6, CW-7, and CW-9.

Groundwater Numerical Model

To evaluate potential fate of the OU4 groundwater plume, the alluvial aquifer is simulated using a combination of Modflow, ModPath and MT3D. Modflow is a program produced by the United States Geological Survey (USGS) which solves the groundwater flow equations discretized to a three-dimensional grid. The current core version from USGS (used here) is MODFLOW-2005 (Harbaugh, 2005). ModPath uses the output from MODFLOW to produce graphical traces for passive particles that follow the direction and velocity of groundwater flow (Pollock, 2016). MT3D is a modeling program that uses the cell-by-cell flow rates calculated by Modflow to simulate the advection, dispersion and diffusion of chemicals dissolved in groundwater (Zheng and Wang, 1999). ModPath is a useful tool to qualitatively visualize groundwater flow but has limited quantitative use since it does not conserve mass. Mass is conserved in MT3D calculations, which allows for quantification of behavior such as dilution and attenuation.

The numerical model grid and boundary conditions are illustrated in Figure 5. The grid is composed of three layers of horizontally uniform 625 ft^2 grid cells. The ground surface / top of layer 1 is derived from the 1/3 arc-second seamless digital elevation model for North America (USGS, 2017). Layer 1 represents the shallow alluvial silt and clay aquitard and is assigned an isotropic hydraulic conductivity layer of 0.01 feet/day. Layers 2 and 3 have a constant thickness and represent the alluvial aquifer and are assigned an isotropic hydraulic conductivity of 300 and 400 feet/day respectively. Constant head boundary conditions are applied to the northern and southern edges of the model grid, and the municipal wells are implemented using well boundary conditions applied to the appropriate grid cells in layer 3. A steady-state Modflow solution is then used to obtain groundwater flows driven by pumping stresses in the alluvial aquifer. This is then used as the basis for ModPath and MT3D models which simulate 5 years of fate and transport in the alluvial aquifer following shut-down of the GWCS extraction wells at the Site. An effective porosity of 0.3 and dispersivity of 1 foot are used in the ModPath and MT3D portions of the calculations.

Five model scenarios are defined based on the annual groundwater use by the City of St. Charles as discussed above (Table 2):

TABLE 2
Groundwater Extraction Rates in GPM for Model Scenarios

Well	CW-6	CW-7	CW-8	CW-9	CW-10	Sum
Scenario 1	200	200	800	1,800	0	3,000
Scenario 2	150	150	400	1,300	1,000	3,000
Scenario 3	0	0	0	1,000	2,000	3,000
Scenario 4	0	0	0	2,000	1,000	3,000
Scenario 5	200	200	600	0	2,000	3,000

The average annual rate of 4.2 MGPD corresponds to an average extraction rate of 3,000 GPM. In scenarios 1 and 2, this is distributed among the wells in similar proportions to the well usage rates reported for 2020. To the best of our understanding, Scenario 2 is reasonably representative of conditions anticipated by the City for the near future. Scenarios 3 and 4 consider a situation where the older wells CW-6, CW-7 and CW-8 are taken out of service. In scenario 5, CW-9 is taken out of service and CW-10 is used at maximum capacity. Scenarios 3, 4 and 5 are extreme configurations which, to the best of our knowledge, are not under consideration.

The Modflow and ModPath results for these five scenarios are shown in Figure 6. Evenly spaced ModPath tracers are introduced in the deep aquifer (model layer 3) and advanced for 5 years. Groundwater flow at the Site always contains a northward component but is deflected towards the east by pumping at CW-10, particularly in Scenario 3 and 5 which indicate some potential for CW-10 to capture some groundwater which has passed beneath the Site.

Residual Source Area

To constrain the geometry of the residual source zone in the MT3D model, historical and recent groundwater analytical data were reviewed. The interpreted residual source zone is shown in Figure 7 and Figure 8. As of June 2021, the majority of residual CVOC mass (as combined concentration of cis-1,2-DCE and Vinyl Chloride) is located in a small area around the on-Site MW-8, MW-13 and MW-41 wells. Most mass appears to be bound in the low hydraulic conductivity silt and clay aquitard near the sump and is only entering the upper aquifer in the vicinity of MW-8. The volume of this impacted area equates to approximately 3 grid cells in the upper aquifer (model layer 2).

Attenuation Mechanisms

Once the GETS extraction wells are deactivated, groundwater passing beneath the Site has some potential to acquire CVOCs from the residual source zone. As the results shown in Figure 6 illustrate, while it is possible for a **trace** amount of CVOC mass to reach CW-6, CW-9, or CW-10, such migration would be very slow (5 years) and it is highly unlikely that such CVOCs would arrive at the wellhead in more than trace amounts. Any new CVOC mass entering the aquifer must disperse across most of the aquifer thickness before it can be captured by a municipal well. The municipal wells also draw in water radially from all directions, only a fraction of which will have come from the direction of the Site. This is particularly true of CW-9 which has four lateral screens situated just above the bedrock.

Here, these attenuation mechanisms are quantified using a MT3D model based on the Modflow results for each scenario. A constant concentration source of a passive (non-reactive) tracer is applied at a unit concentration in an area beneath the Site to simulate a hypothetical release of new CVOCs into the aquifer following shut down of the GETS wells. This is a conservative approximation, as in reality, this release would be a mixture of cis-1,2-DCE and Vinyl Chloride which will experience more attenuation than the passive tracer due to sorption to aquifer solids and continued bio-degradation. Groundwater at the Site has been and continues to be amended with an organic substrate to promote destruction of CVOC mass by microbial dechlorination. This enhanced biological activity will continue in groundwater leaving the Site.

Model Results

For each of the scenarios, a MT3D simulation is performed assigning a constant unit (1 mg/L) concentration boundary condition to 3 residual source area grid cells in model layer 2 and allowing the plume to develop for 5 years.

SCENARIO 1

Results from the Scenario 1 model are shown in Figure 9. A narrow plume of the tracer develops north of the Site, extending to near well CW-6. The time series plot in Figure 9 shows the concentration of the tracer in the upper aquifer at the CW-6 location, and the dilute concentration captured by CW-6 in the lower aquifer. The tracer plume does not reach CW-10. Concentration is given as a fraction of concentration at the residual source zone; the dilution factor is then the reciprocal of the fractional concentration observed in the pumping well.

The tracer plume first arrives at CW-6 after approximately 300 days and has equilibrated to near steady state by 600 days. The maximum concentration observed in CW-6 is 0.016; a dilution factor of 63. This indicates that a cis-1,2-DCE or vinyl chloride source strength of 1,000 µg/L would result in those constituents detected in CW-6 in concentrations of approximately 1,000/63 = 16 µg/L.

This scenario is the most representative of aquifer conditions before the installation of CW-10, and the geometry and extent of the tracer plume in the upper aquifer is similar to the pre-remedy delineated OU4 CVOC plume. Prior to remediation, the source strength was stronger; although there have been sporadic CVOC detections at CW-6, they have never been as high as 16 µg/L. Historically, cis-1,2-DCE was detected in CW-6 up to a qualified concentration of 3.2 µg/L; TCE and vinyl chloride have never been detected. This demonstrates the conservative nature of these model results, as the passive tracer is not attenuated by the sorption and bio-degradation processes that reduce CVOC concentrations.

SCENARIO 2

Results from the Scenario 2 model are shown in Figure 10. The addition of pumping stresses from CW-10 causes the tracer plume to deviate towards the east and experience more horizontal dispersion. The tracer plume again arrives at CW-6 after approximately 300 days and reaches quasi steady state after approximately 700 days. The tracer plume does not reach CW-10. The maximum concentration observed in water extracted from CW-6 is 0.013; a dilution factor of 77. This indicates that a cis-1,2-DCE or vinyl chloride residual source strength of 1,000 µg/L would result in those constituents detected in CW-6 in concentrations of approximately 1,000/77 = 13 µg/L, similar to the Scenario 1 result.

This scenario represents current pumping rates and those anticipated for the near future. Here, groundwater flow continues to be dominated by the combination of CW-6, CW-7 and CW-9. CW-10 does exert an influence but does not capture groundwater passing beneath the Site.

SCENARIO 3

Results from Scenario 3 are shown in Figure 11. Here, the opposing pumping stresses from CW-9 and CW-10 cause the tracer plume to disperse across a wide area of the upper aquifer. The tracer plume arrives at CW-10 after approximately 600 days. The distributed nature of the plume causes a gradual rise in concentrations rather than a sharp increase followed by a quasi-steady state. The maximum tracer concentration observed in water extracted from CW-10 is 0.0015; a dilution factor of 670. This indicates that a cis-1,2-DCE or vinyl chloride residual source strength of 1,000 µg/L would result in those constituents detected in CW-10 in concentrations of approximately 1,000/670 = 1.5 µg/L. This is below the MCL values for those constituents (70 and 2 µg/L, respectively), as well as typical detection limits.

This is an unlikely scenario in which CW-10 is operated at maximum capacity and CW-9 below capacity for a five-year period of time.

SCENARIO 4

Results from Scenario 4 are shown in Figure 12. While the influence of CW-10 causes some horizontal dispersion the tracer plume is largely controlled by CW-9. In this case, CW-6 is not operating so a time series are shown for CW-9. The tracer plume arrives at CW-9 after approximately 400 days and reaches a quasi-steady state by 700 days. The maximum tracer concentration observed in water extracted from CW-9 is 0.0020; a dilution factor of 500. This indicates that a cis-1,2-DCE or vinyl chloride residual source strength of 1,000 µg/L would result in those constituents detected in CW-9 in concentrations of approximately 1,000/500 = 2 µg/L; however, this dilution factor is probably underestimated, as CW-9 is a radial well with four horizontal screens situated just above the bedrock as opposed to the vertical construction of the other municipal wellbores.

SCENARIO 5

Results from Scenario 5 are shown in Figure 13. Without pumping from CW-9, the tracer plume develops between the Site and CW-10. The plume arrives at CW-10 after approximately 400 days and reaches a quasi-steady state by 800 days. The maximum tracer concentration observed in water extracted from CW-10 is 0.0018; a dilution factor of 560. This indicates that a cis-1,2-DCE or vinyl chloride residual source strength would result in those constituents in CW-10 at concentrations of approximately 1,000/560 = 1.8 µg/L, again below MCL values for those constituents and below typical detection limits.

Scenario 5 considers a situation in which CW-9 is completely inactive for a period of five or more years. To the best of our understanding, the City plans to continue to rely on CW-9 as a primary supply well.

Comparison to Previous Results

In the OU3 RIFS, a Modflow/ModPath model was used to compare hypothetical travel times from the OU3 area to various municipal wells in the Elm Point wellfield (Geotechnology, 2005). Excerpts from the results are shown in Figure 14. At the time, Wells CW-4 and CW-5 were still in use; CW-9 was newly installed, and CW-10 did not yet exist. These results showed that while some natural flow conditions exist in the OU3 area, groundwater flow at the Site is controlled entirely by pumping stresses from the municipal wells. When pumping from (former) CW-4 and CW-8 only, groundwater flow at the Site and OU4 area was to the east; in the other two scenarios it was to the north. Since CW-4 and CW-5 are no longer in use and primary production is from CW-9, the scenario showing eastern flow is no longer relevant. It is noteworthy that these 2005 results indicate significant changes in groundwater conditions at the Site when CW-9 is in operation.

The travel times were calculated from ModPath particle tracks initiated in various OU3 area locations. For a scenario with CW-9 operating at expected rates, the model indicated a travel time of 4.8, 6.5 and 24 years from the OU-3 area to CW-9 (as well as one particle that was not captured by CW-9), generally consistent with the travel times indicated in the new ModPath results in this CSM. The longer travel times appear to be the result of particles that were trapped for some time in areas of lower hydraulic conductivity near the edge of the alluvial aquifer and are not representative of faster groundwater velocities at the Site.

Source Zone Depletion and Plume Attenuation

As noted, the residual source has been treated by ISCO injections and bio-augmentation, and the bio-augmentation treatments will continue after the GETS is deactivated. The results from Scenarios 1 – 5 are highly conservative in that such ongoing augmentation efforts are not reflected and as a consequence the source zone is given a constant strength and the tracer does not degrade after it is introduced into the aquifer. In reality, steadily declining concentrations have been observed in the source zone. A time series of CVOC concentrations in monitoring well MW-8 is shown in Figure 15. The effect of the bio-augmentation is to promote the microbial dechlorination of TCE to cis-1,2-DCE; cis-1,2-

DCE to vinyl chloride, and vinyl chloride to ethene. The depletion of cis-1,2-DCE is reasonably represented as an exponential depletion with a half-life of one year.

Figure 16 shows the result of applying mass decay to the tracer in MT3D with a half-life of 2, 1 and 0.5 years for Scenario 3. This conceptually illustrates the effect of ongoing microbial dechlorination after the amended groundwater leaves the Site. Figure 17 shows the result of applying a one-year half-life to both the tracer and the residual source zone strength. The maximum concentration observed in water extracted from CW-10 is 0.00015 after approximately 1,000 days; a dilution and attenuation of present-day concentrations by a factor of 6,700, which is approximately one order of magnitude more attenuated than the purely passive tracer. This indicates that a present-day cis-1,2-DCE or vinyl chloride residual source strength of 1,000 µg/L would result in those constituents appearing in CW-10 after 1,000 days at concentrations of approximately 1,000/6,700 = 0.15 µg/L, below the detection limit of standard analytical methods used for drinking water.

Conclusions

Under expected operating conditions of the municipal wells, it is unlikely that groundwater passing beneath the Site will reach CW-10. It is possible that CW-10 could capture groundwater passing beneath the Site but only if extraction from CW-9 was greatly decreased and CW-10 was operated at maximum capacity for a prolonged period of time. This condition is not expected in the foreseeable future. The numerical Modflow/MT3D groundwater fate and transport model indicate that water potentially containing CVOCs from the Site would not appear in CW-10 for at least 400 days, and any Site-related CVOCs would likely be diluted below detection limits in the extracted groundwater. Adding degradation and source zone depletion to Scenario 3 demonstrates that the models are conservative as the residual plume will be more attenuated than the passive tracer indicates. Modeling of reactive transport of cis-1,2-DCE and vinyl chloride instead of a passive tracer is possible with MT3D but will show an even more attenuated and slowly moving plume as CVOCs are sorbed to aquifer solids.

The 400-day travel time indicates that changes in groundwater flow that could affect CW-10 would be preceded by observable changes at the Site at least one year in advance. This would appear in the form of increasing CVOC concentrations in MW-02 as the residual plume was drawn eastward from its current trajectory. We recommend ongoing observation and trend analysis of MW-02 to look for these indicators of changing conditions. It is our understanding that the GETS equipment will remain in place and may be re-activated if this condition is observed.

We appreciate the opportunity to provide conceptual site model development services on this project. Please do not hesitate to call if you have any questions or comments.

Sincerely yours,
HALEY & ALDRICH, INC.

J.P. Brandenburg
Senior Geologist

Jay Peters
Technical Expert

Enclosures:

References

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15. Zheng, C. and P. Wang, MT3D MS: A modular three-dimensional multispecies transport model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems, Documentation and user's guide. U.S. Army Corps of Engineers Contract Report SERDP-99-1, 1999.

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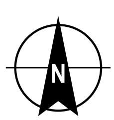
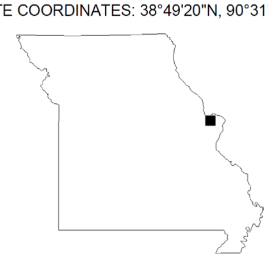
MAP SOURCE: ESRI

SITE COORDINATES: 38°49'20"N, 90°31'46"W





LOCATIONS AND OPERABLE UNIT BOUNDARIES APPROXIMATE

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PROJECT LOCUS, OPERABLE UNITS, AND MUNICIPAL WELLS

APPROXIMATE SCALE: 1 IN = 2000 FT
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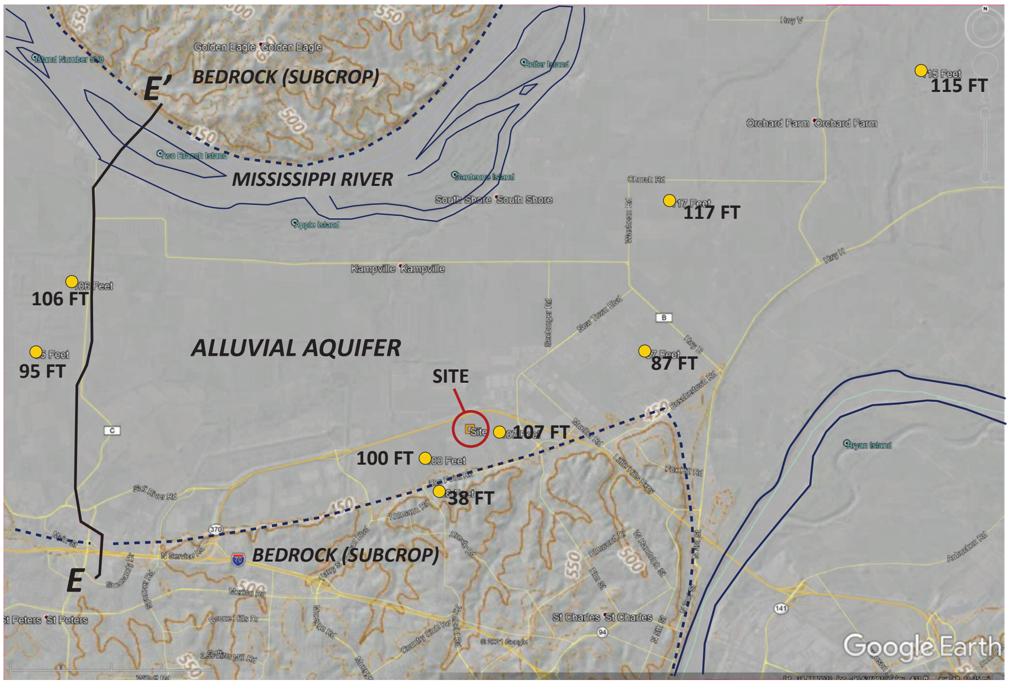
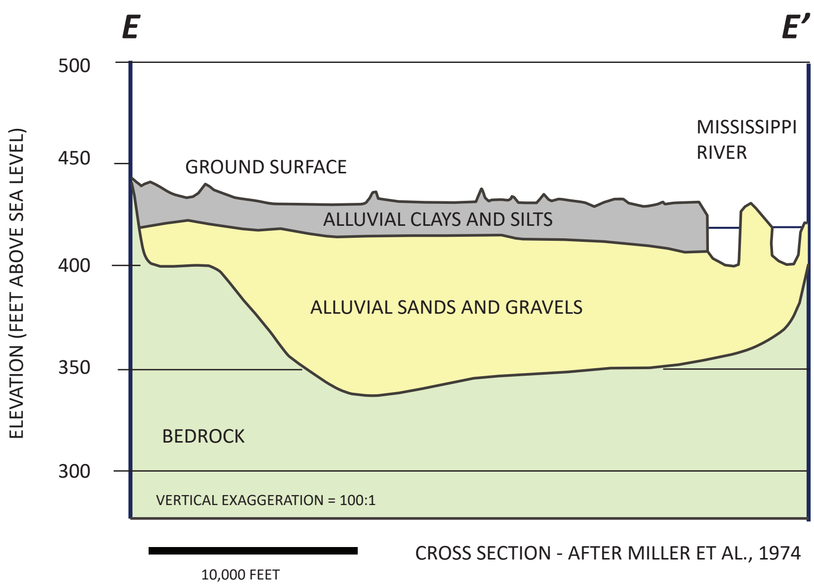
FIGURE 1



ALLUVIAL AQUIFER: MAP - AFTER MILLER ET AL., 1974

100 FT - OBSERVED AQUIFER THICKNESS



CROSS SECTION - AFTER MILLER ET AL., 1974

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THE MISSISSIPPI RIVER
ALLUVIAL AQUIFER

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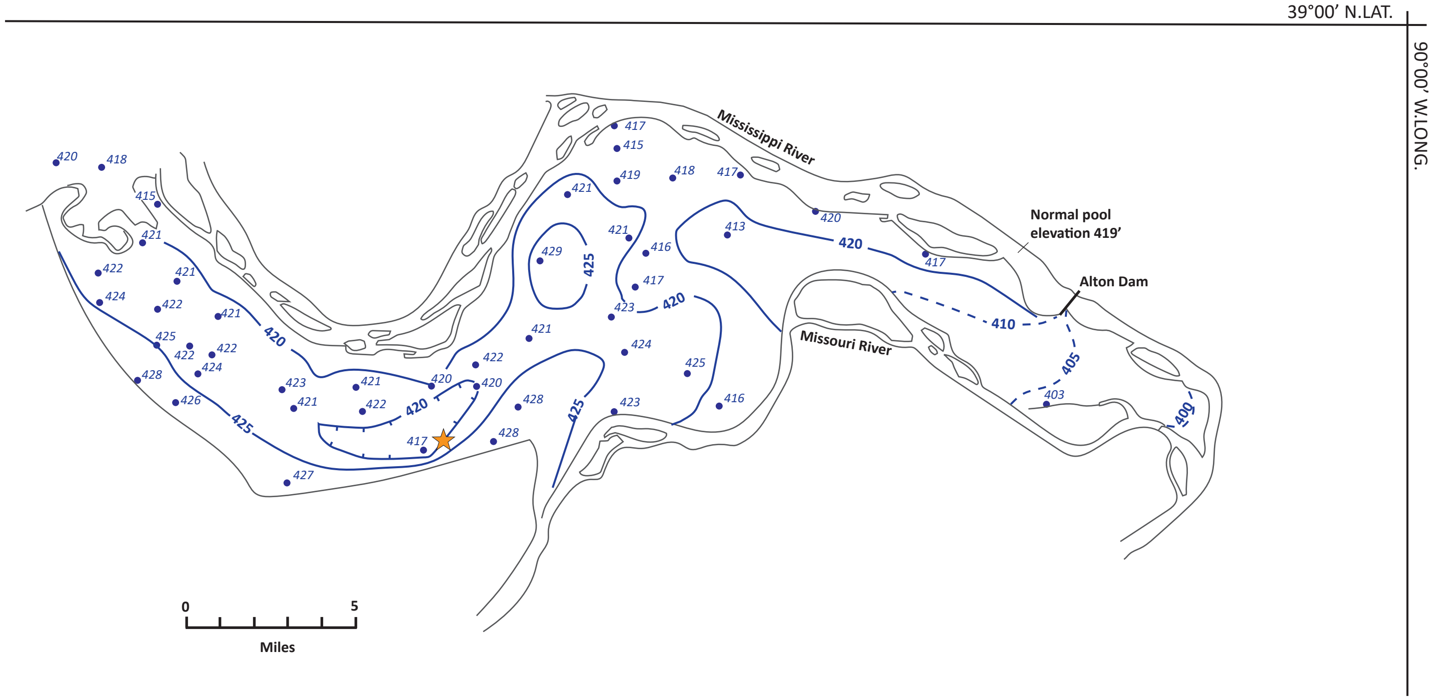
FIGURE 2



REDRAWN AFTER: *Miller D., L. Emmett, J. Skelton, H. Jeffery and J. Barks. 1974. Water Resources of the St. Louis Area, Missouri. Water Resources Report 30. US and Missouri Geological Surveys. 114 pp.*

EXPLAINATION

425 — POTENTIOMETRIC CONTOUR SHOWING ALTITUDE OF POTENTIOMETRIC SURFACE. CONTOUR INTERVAL 5 FEET. DATUM IS MEAN SEA LEVEL. HACHURES INDICATE DEPRESSIONS

• 422 — OBSERVATION WELL AND ALTITUDE OF POTENTIOMETRIC SURFACE IN FEET ABOVE MEAN SEA LEVEL.

★ LOCATION OF SITE

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HISTORICAL GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER

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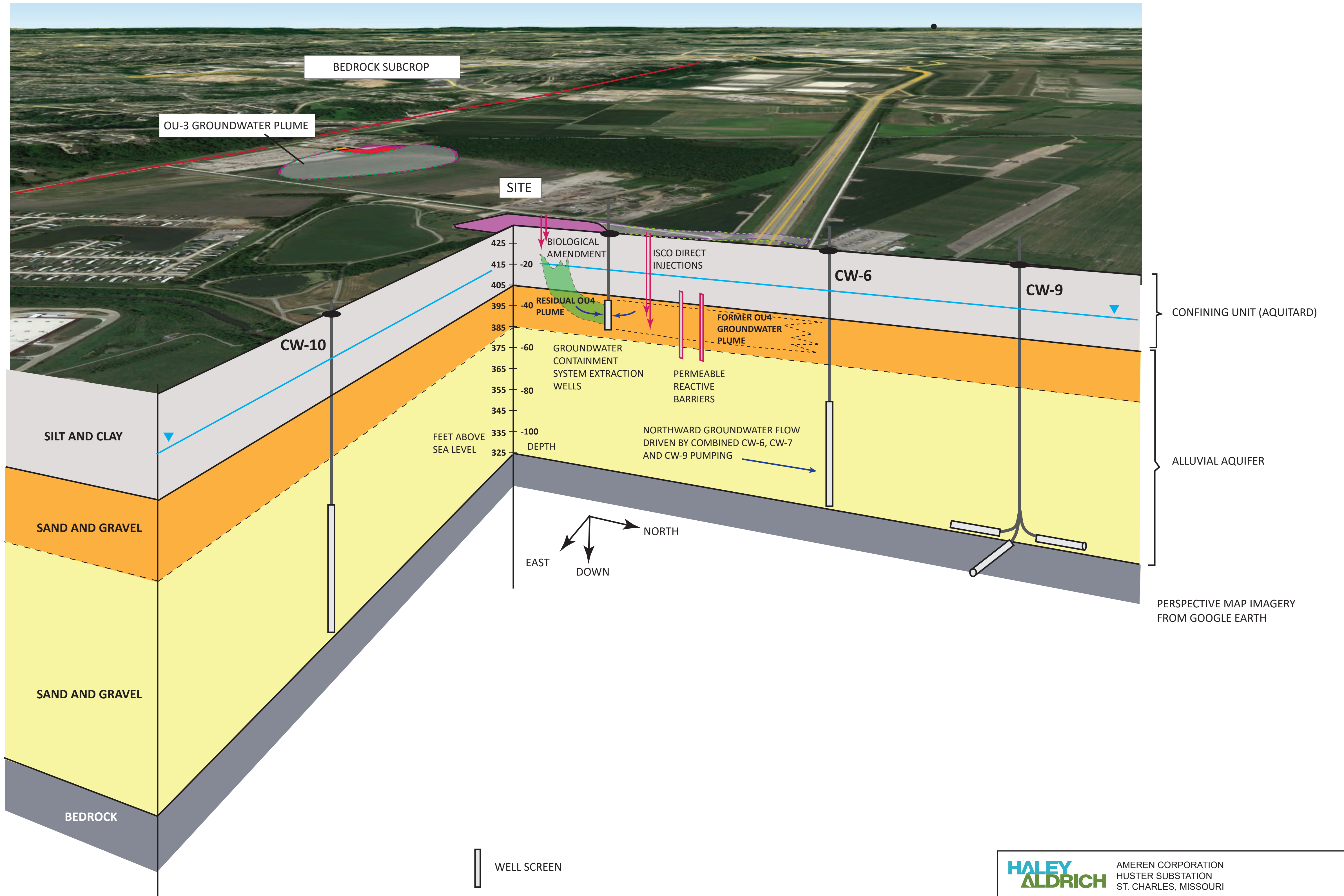
FIGURE 3



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CONCEPTUAL SITE MODEL

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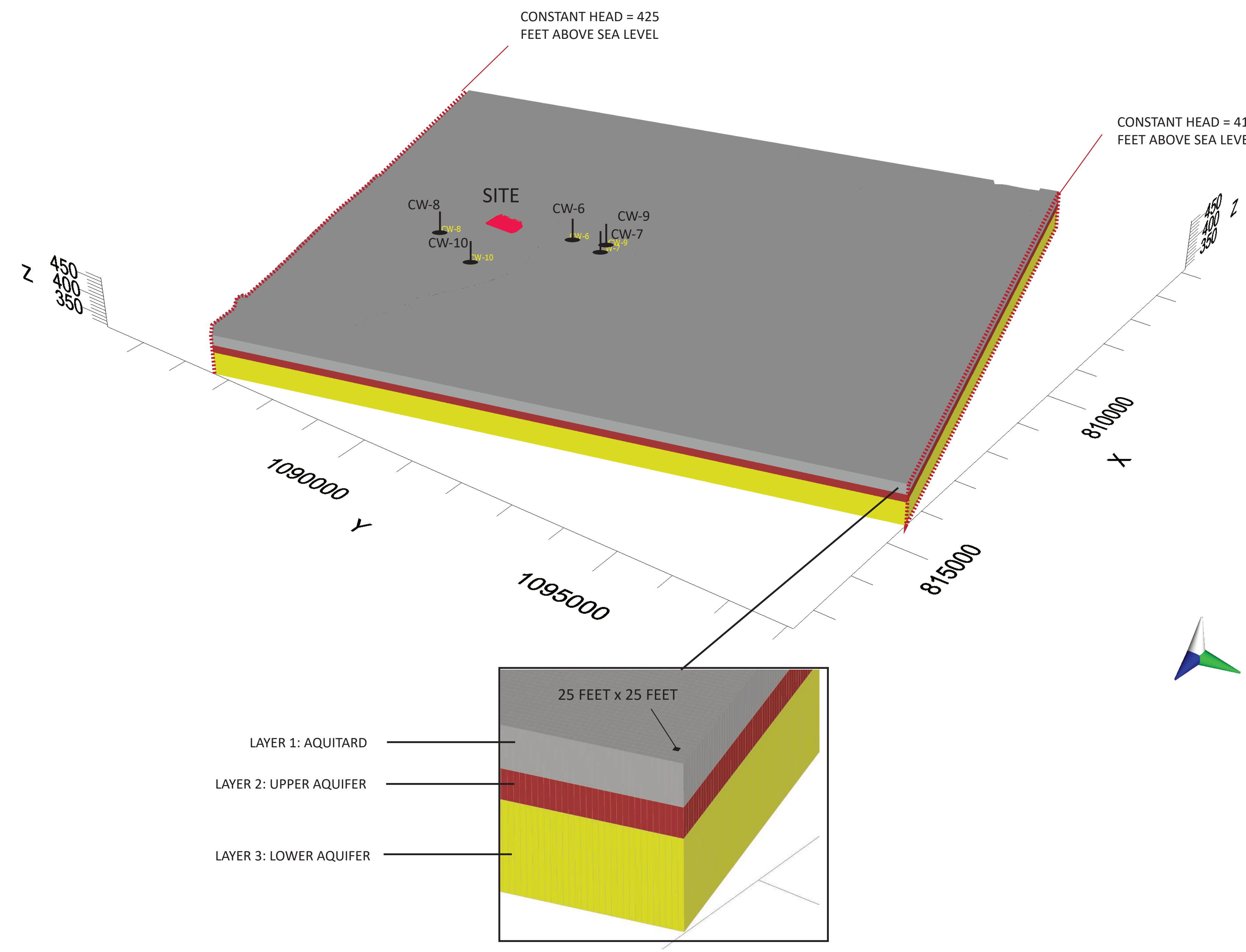
FIGURE 4



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NUMERICAL MODEL GRID
AND BOUNDARY CONDITIONS

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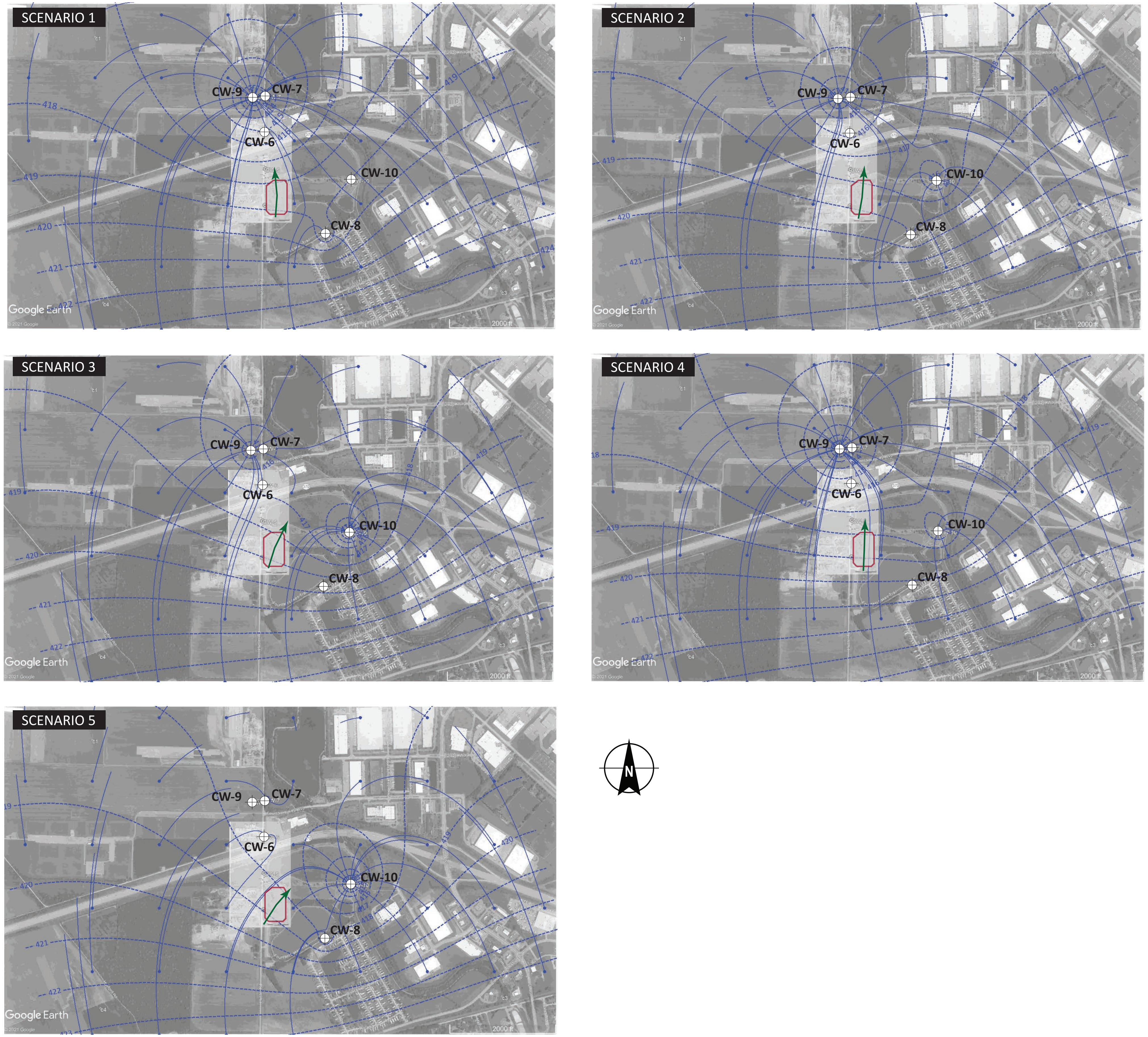
FIGURE 5



EXPLAINATION

420 MODEL GROUNDWATER ELEVATION CONTOURS (FEET ABOVE SEA LEVEL)

MODPATH PARTICLE TRACE
CIRCLE = STARTING POSITION
LENGTH = 5-YEAR TRAVEL TIME

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

MODELED GROUNDWATER FLOW DIRECTION AT SITE

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MODELED GROUNDWATER FLOW

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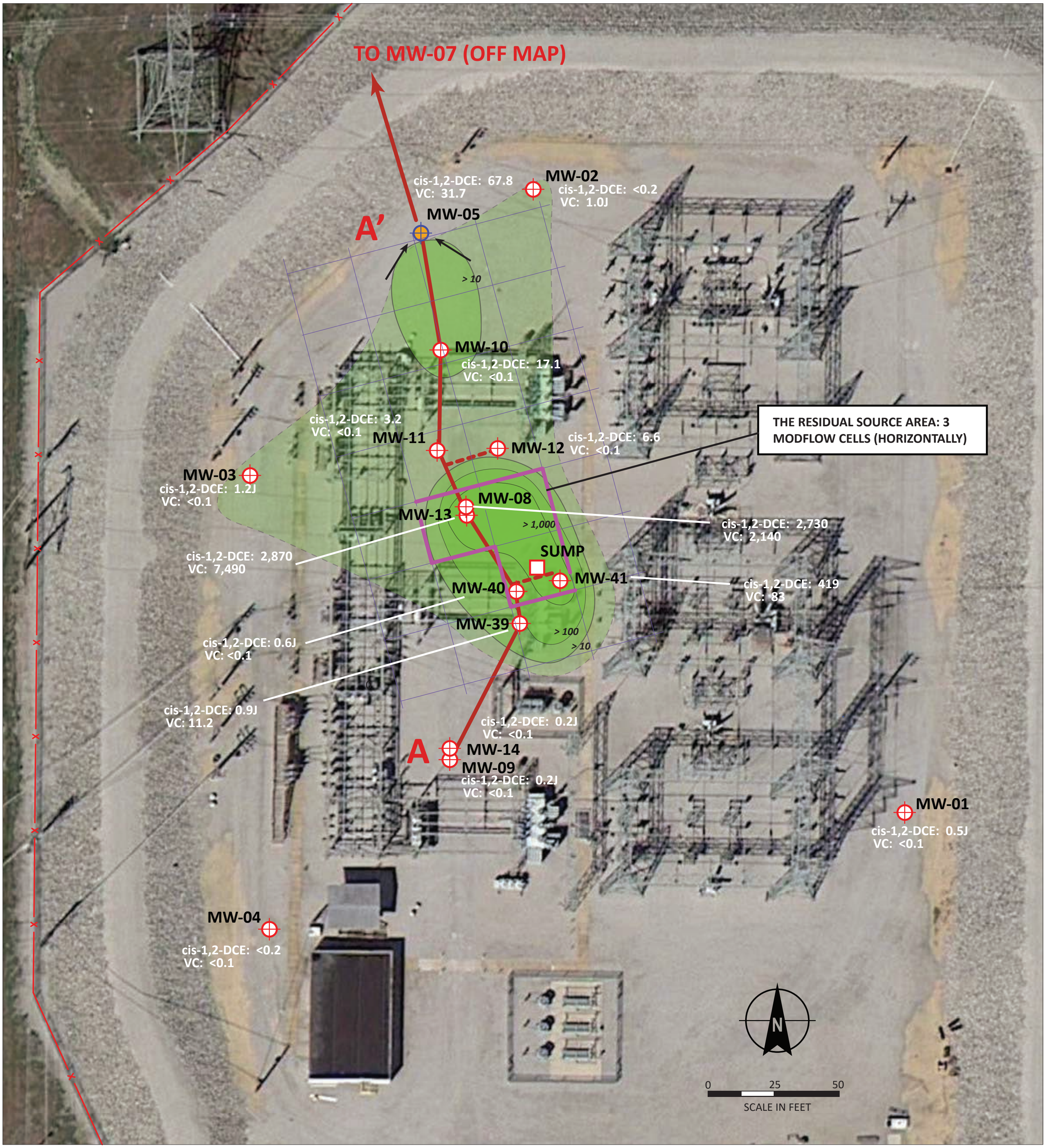
FIGURE 6



cis-1,2-DCE + VINYL CHLORIDE
Groundwater Concentration

- >1,000 µg/L
- >100 µg/L
- >10 µg/L
- >1 µg/L

JUNE 2021 DATA SHOWN

- MONITORING WELL
- GROUNDWATER EXTRACTION WELL
- CROSS SECTION (PROJECTION DASHED)
- DIMENSIONS OF MODFLOW GRID

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RESIDUAL SOURCE ZONE
MAP VIEW

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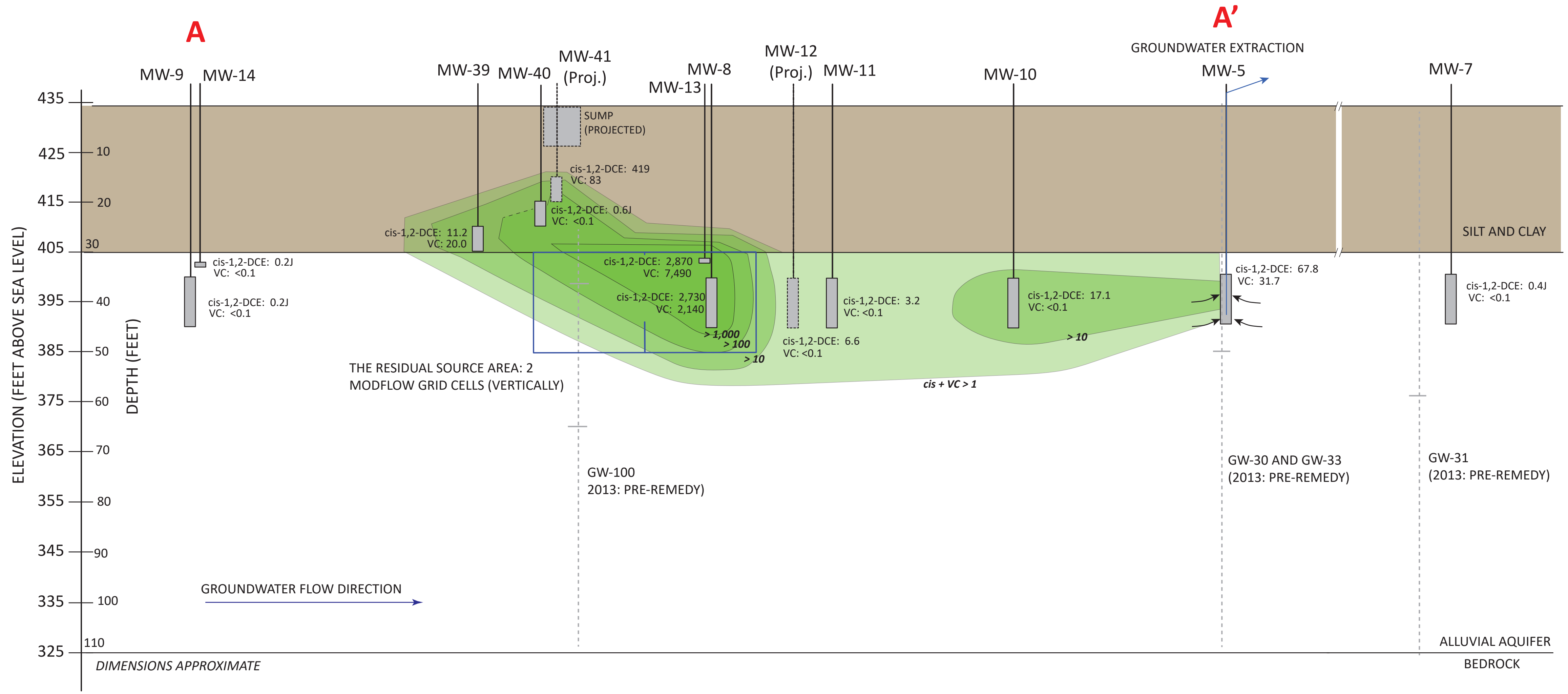
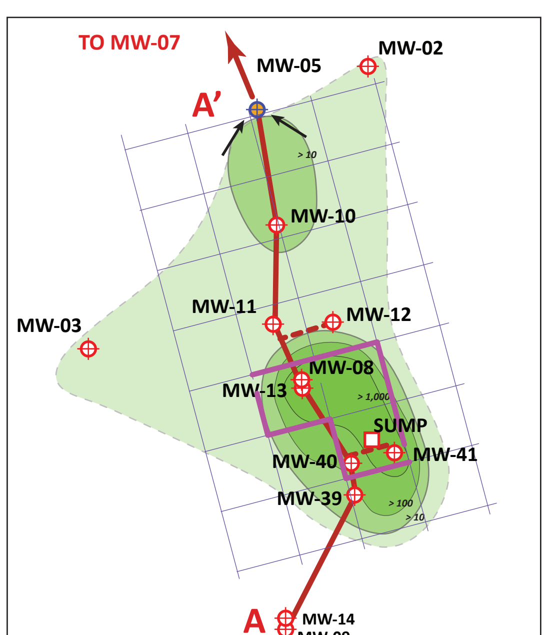
FIGURE 7





cis-1,2-DCE + VINYL CHLORIDE
GROUNDWATER CONCENTRATION

- >1,000 µg/L
- >100 µg/L
- >10 µg/L
- >1 µg/L

JUNE 2021 DATA SHOWN

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RESIDUAL SOURCE ZONE
CROSS SECTION VIEW

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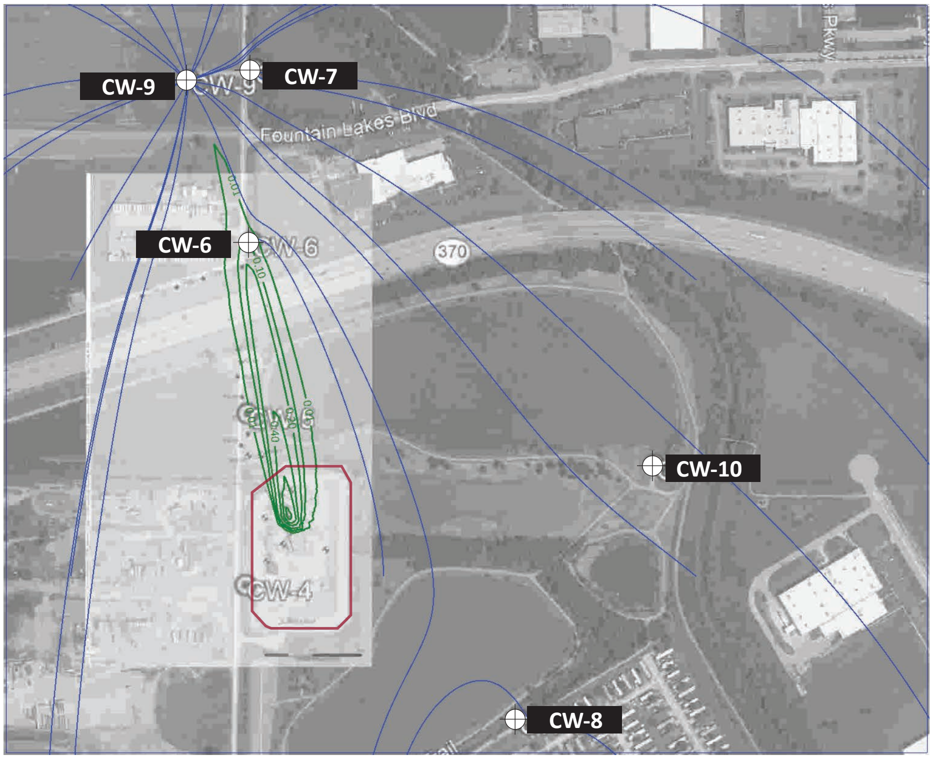
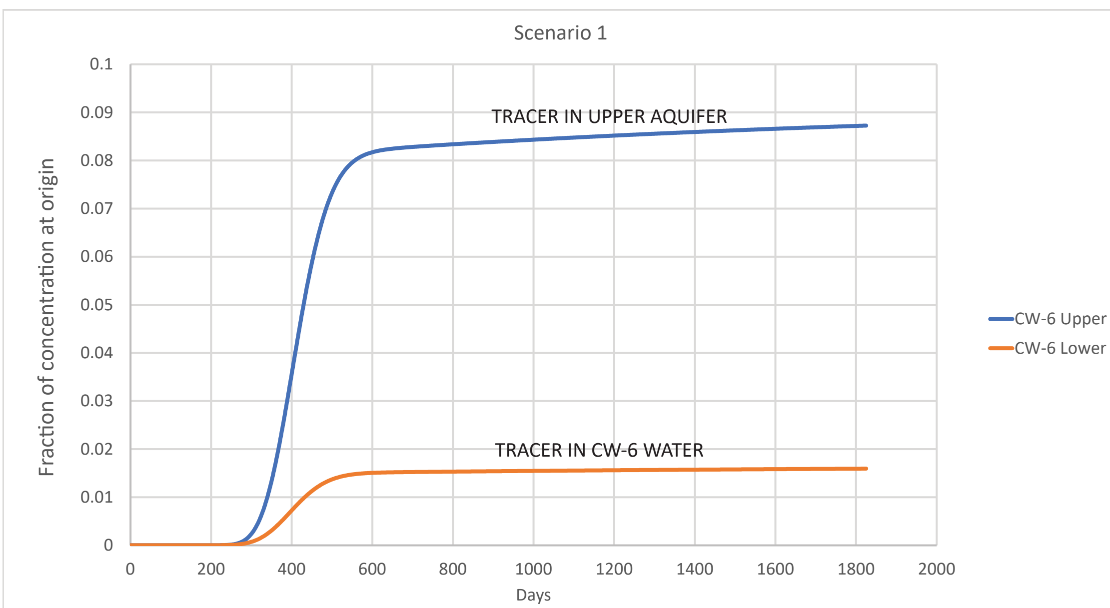
FIGURE 8

CW-6: 200 GPM
CW-7: 200 GPM
CW-8: 800 GPM
CW-9: 1,800 GPM
CW-10: 0 GPM





MAP EXPLAINATION

MODPATH PARTICLE TRACE
LENGTH = 5-YEAR TRAVEL TIME

0.3 CONTOURS: MT3D PASSIVE TRACER CONCENTRATION IN UPPER AQUIFER AFTER 5 YEARS (CONCENTRATION AT ORIGIN = 1.0)

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

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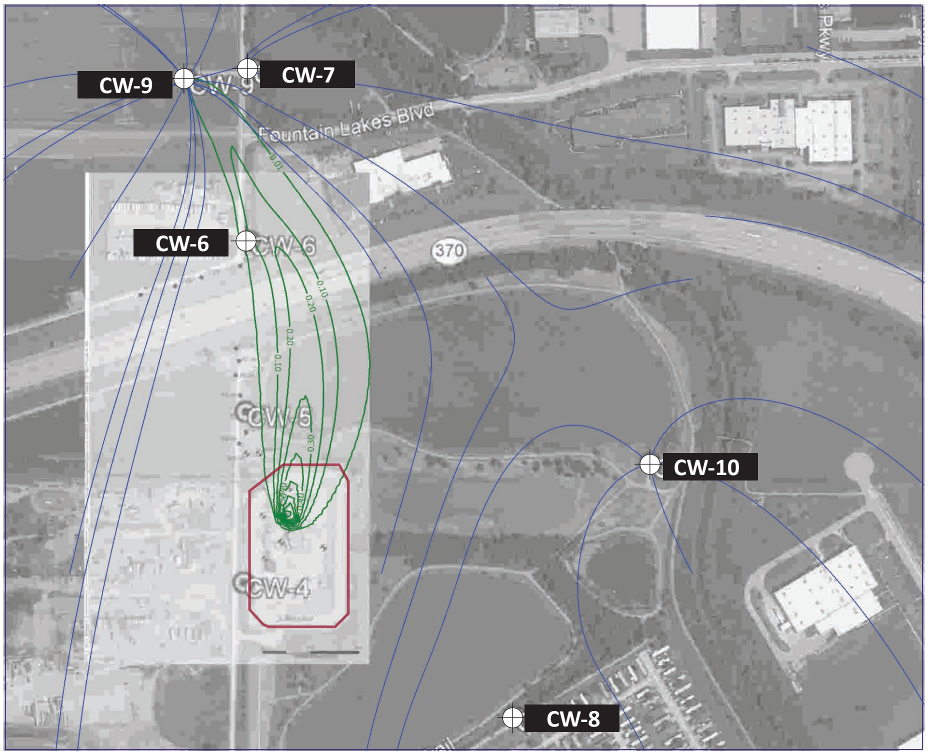
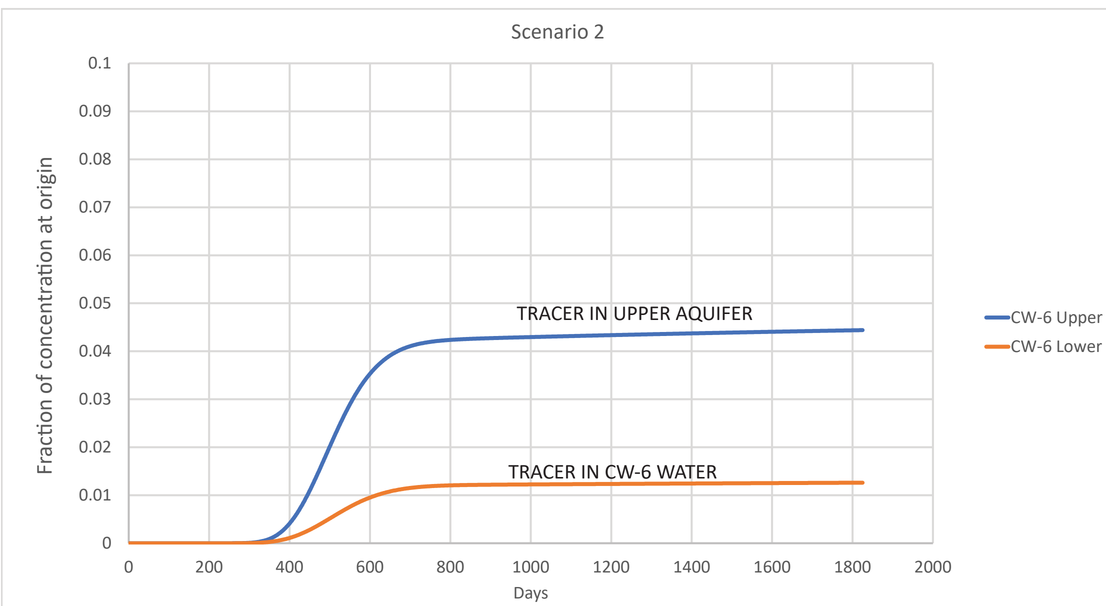
SCENARIO 1
MODEL RESULTS

SEPTEMBER 2021

FIGURE 9

CW-6: 150 GPM
CW-7: 150 GPM
CW-8: 400 GPM
CW-9: 1,300 GPM
CW-10: 1,000 GPM





MAP EXPLAINATION

MODPATH PARTICLE TRACE
LENGTH = 5-YEAR TRAVEL TIME

0.3 CONTOURS: MT3D PASSIVE TRACER CONCENTRATION IN UPPER AQUIFER AFTER 5 YEARS (CONCENTRATION AT ORIGIN = 1.0)

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

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HUSTER SUBSTATION
ST. CHARLES, MISSOURI

SCENARIO 2
MODEL RESULTS

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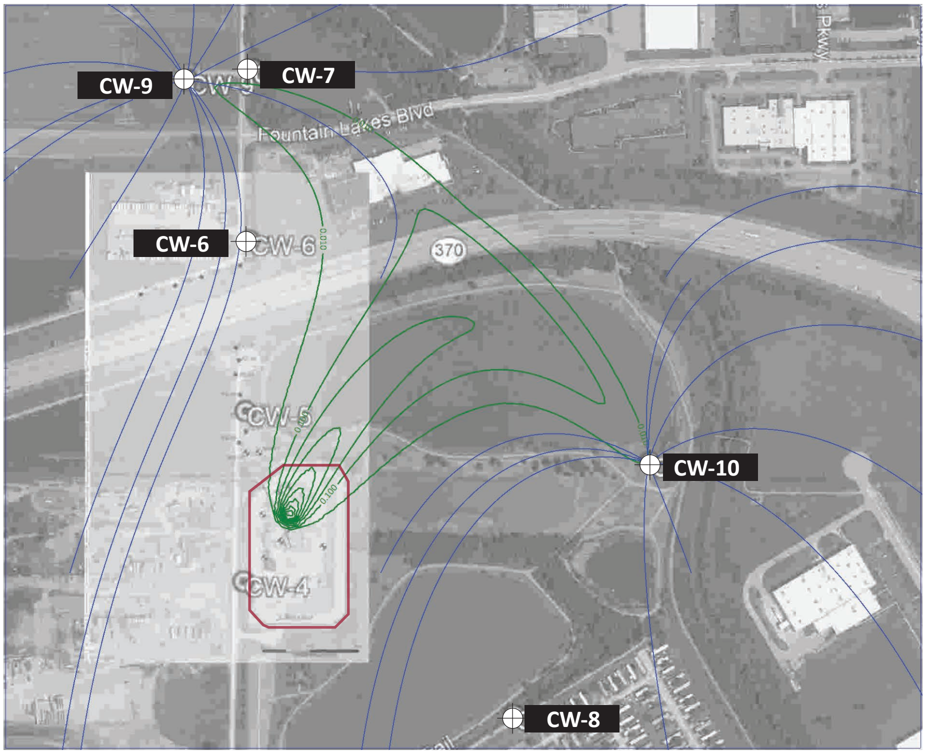
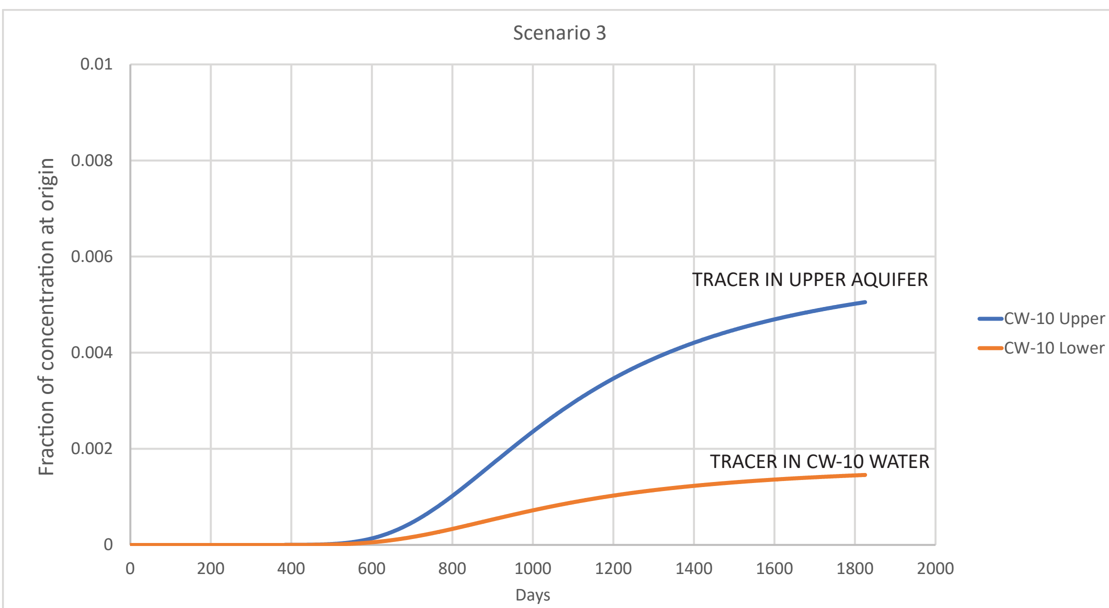
FIGURE 10

CW-6: 0 GPM
CW-7: 0 GPM
CW-8: 0 GPM
CW-9: 1,000 GPM
CW-10: 2,000 GPM





MAP EXPLAINATION

MODPATH PARTICLE TRACE
LENGTH = 5-YEAR TRAVEL TIME

0.3 CONTOURS: MT3D PASSIVE TRACER CONCENTRATION IN UPPER AQUIFER AFTER 5 YEARS (CONCENTRATION AT ORIGIN = 1.0)

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

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SCENARIO 3
MODEL RESULTS

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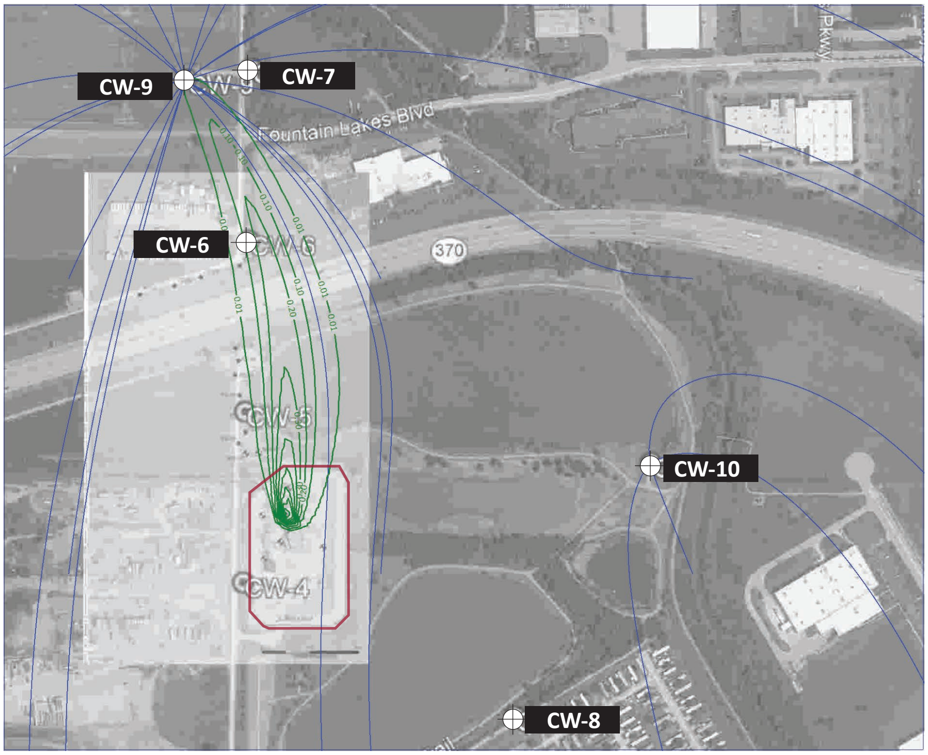
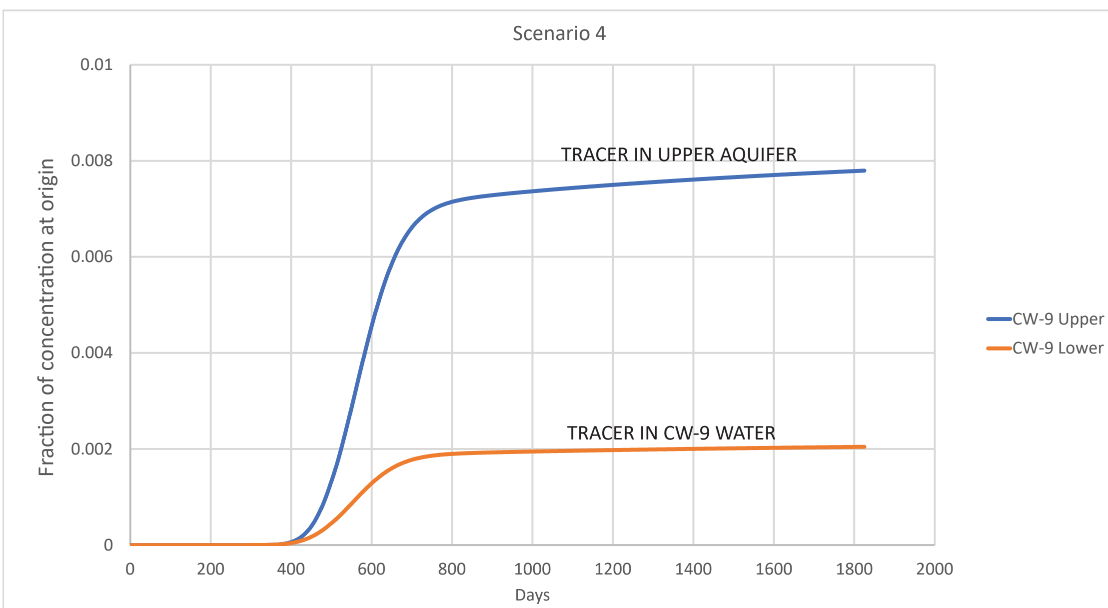
FIGURE 11

CW-6: 0 GPM
CW-7: 0 GPM
CW-8: 0 GPM
CW-9: 2,000 GPM
CW-10: 1,000 GPM





MAP EXPLAINATION

MODPATH PARTICLE TRACE
LENGTH = 5-YEAR TRAVEL TIME

0.3 CONTOURS: MT3D PASSIVE TRACER CONCENTRATION IN UPPER AQUIFER AFTER 5 YEARS (CONCENTRATION AT ORIGIN = 1.0)

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

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ST. CHARLES, MISSOURI

SCENARIO 4
MODEL RESULTS

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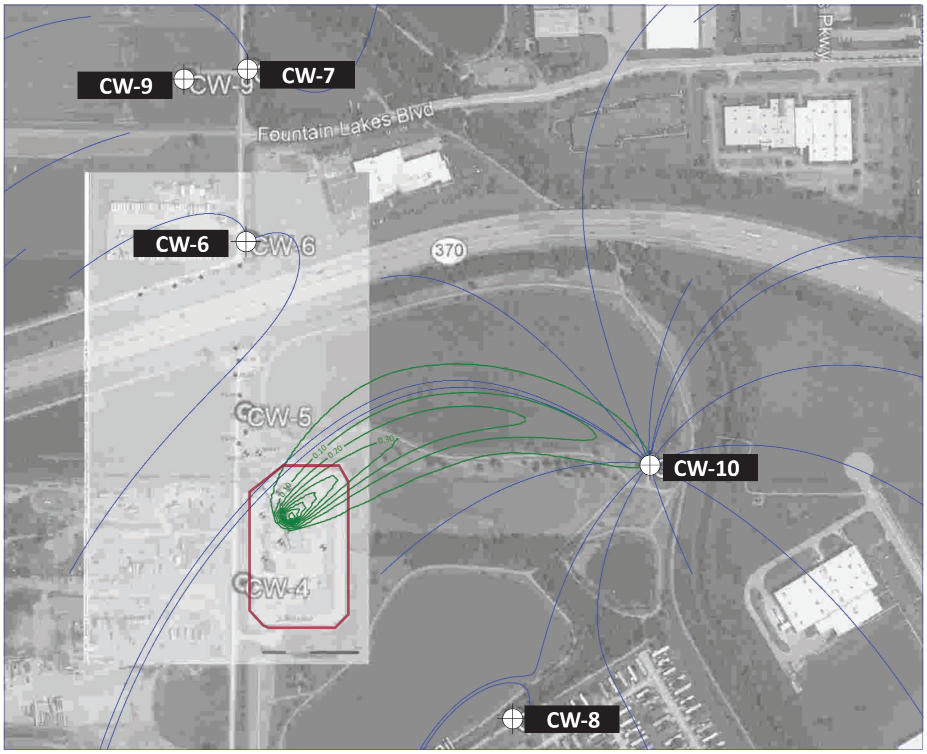
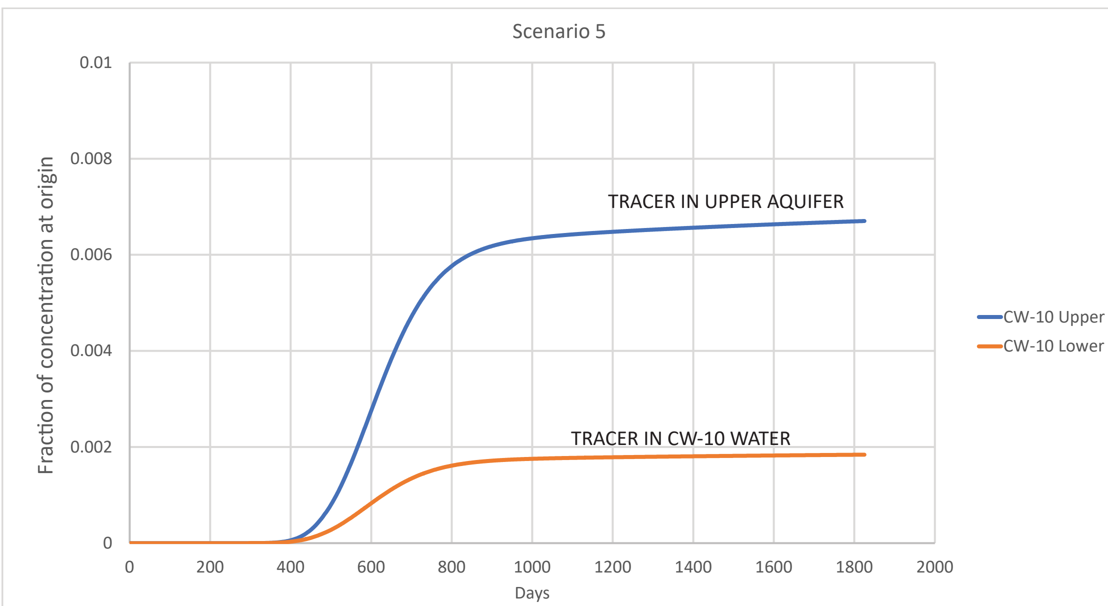
FIGURE 12

CW-6: 200 GPM
CW-7: 200 GPM
CW-8: 600 GPM
CW-9: 0 GPM
CW-10: 2,000 GPM





MAP EXPLAINATION

MODPATH PARTICLE TRACE LENGTH = 5-YEAR TRAVEL TIME

0.3 CONTOURS: MT3D PASSIVE TRACER CONCENTRATION IN UPPER AQUIFER AFTER 5 YEARS (CONCENTRATION AT ORIGIN = 1.0)

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

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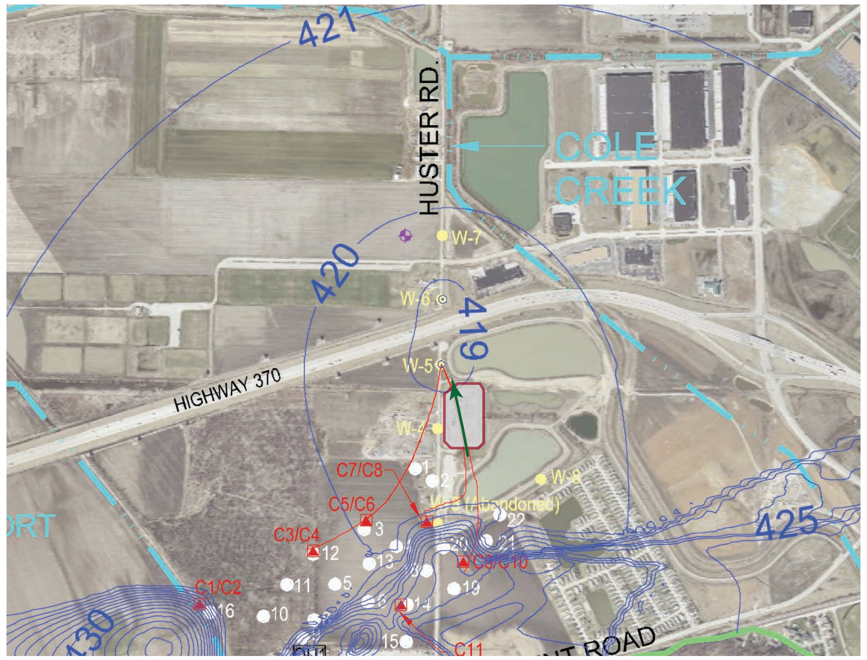
SCENARIO 5
MODEL RESULTS

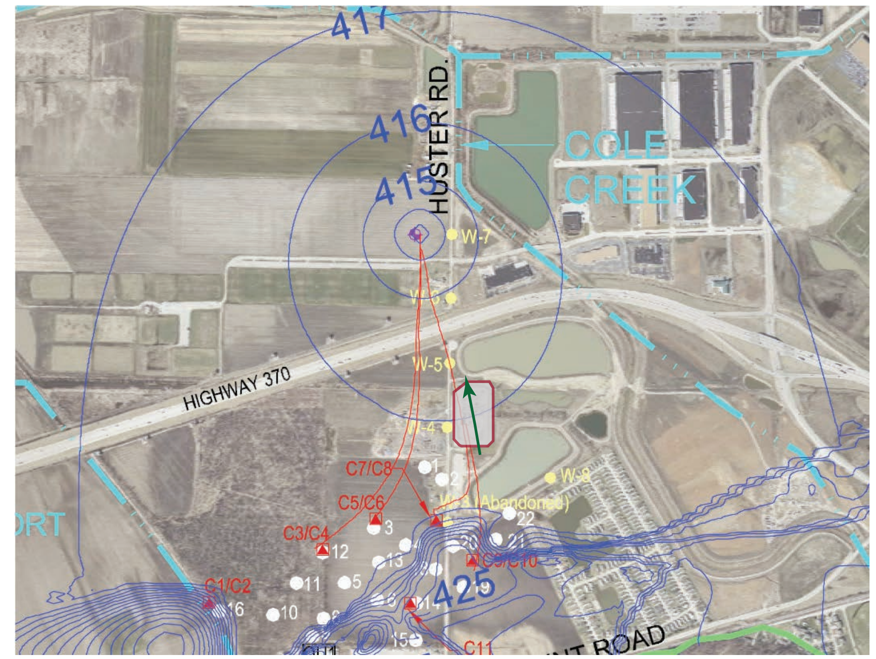
SEPTEMBER 2021

FIGURE 13

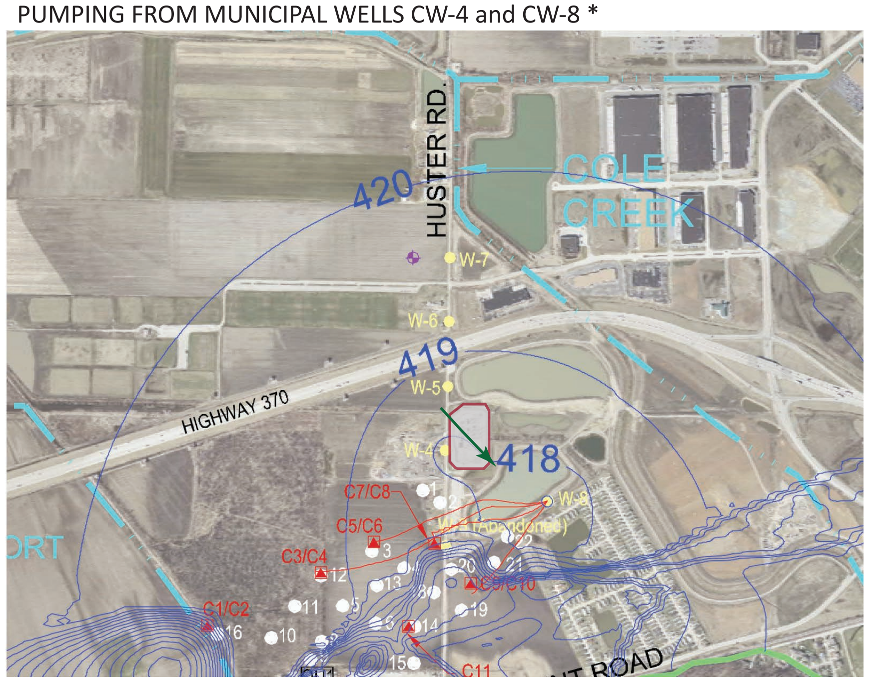
PUMPING FROM MUNICIPAL WELLS CW-5 and CW-6 *



PUMPING FROM MUNICIPAL WELLS CW-9 *



PUMPING FROM MUNICIPAL WELLS CW-4 and CW-8 *



SOURCE: PLATES 41, 42 AND 43 IN RIFS (GEOTECHNOLOGY, 2005)
SITE LOCATION AND GROUNDWATER FLOW DIRECTION ARE SUPERIMPOSED
*NOTE: MUNICIPAL WELLS WERE LABELED “W-” INSTEAD OF “CW-” IN THE RIFS STUDY

EXPLAINATION

420 — MODEL GROUNDWATER ELEVATION CONTOURS (FEET ABOVE SEA LEVEL)

MODPATH PARTICLE TRACE
TRIANGLE = STARTING POSITION

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

MODELED GROUNDWATER FLOW DIRECTION AT SITE

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PREVIOUS MODEL RESULTS

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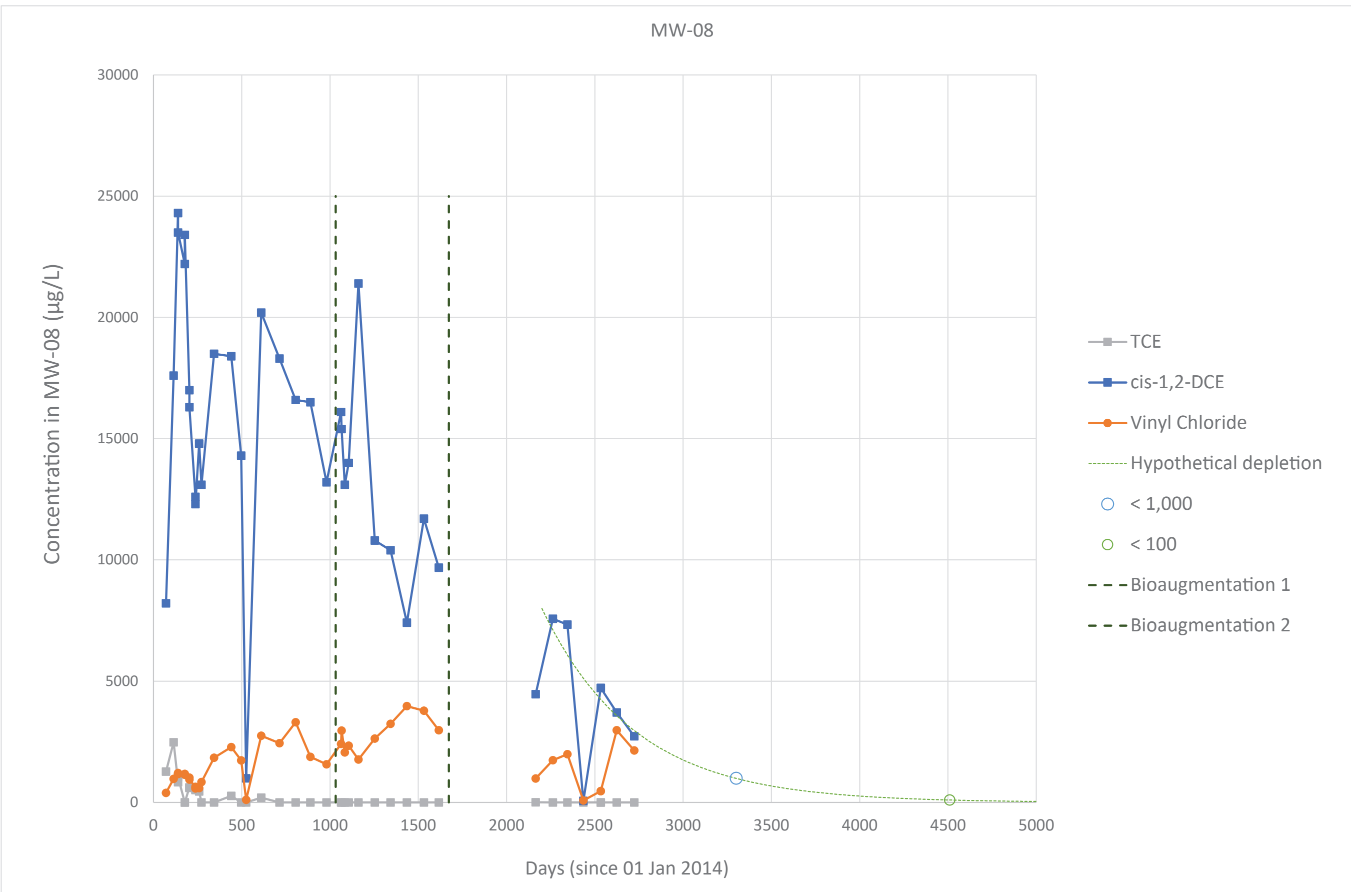
FIGURE 14



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SOURCE ZONE DEPLETION

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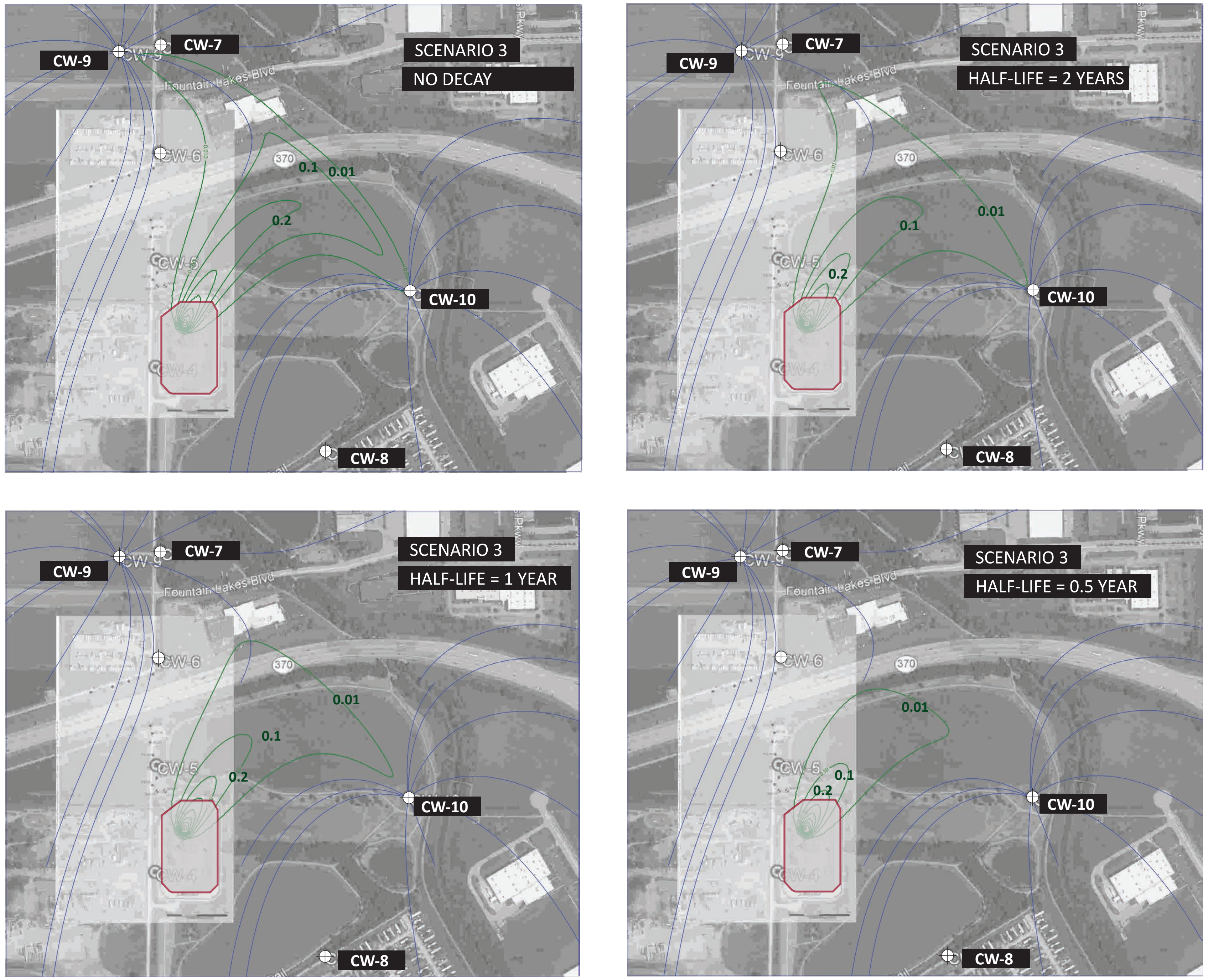
FIGURE 15



EXPLAINATION

420 — MODEL GROUNDWATER ELEVATION CONTOURS (FEET ABOVE SEA LEVEL)

MODPATH PARTICLE TRACE LENGTH = 5-YEAR TRAVEL TIME

0.3 — CONTOURS: MT3D PASSIVE TRACER CONCENTRATION IN UPPER AQUIFER AFTER 5 YEARS (CONCENTRATION AT ORIGIN = 1.0)

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

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SCENARIO 3 MODEL RESULTS WITH DEGRADATION

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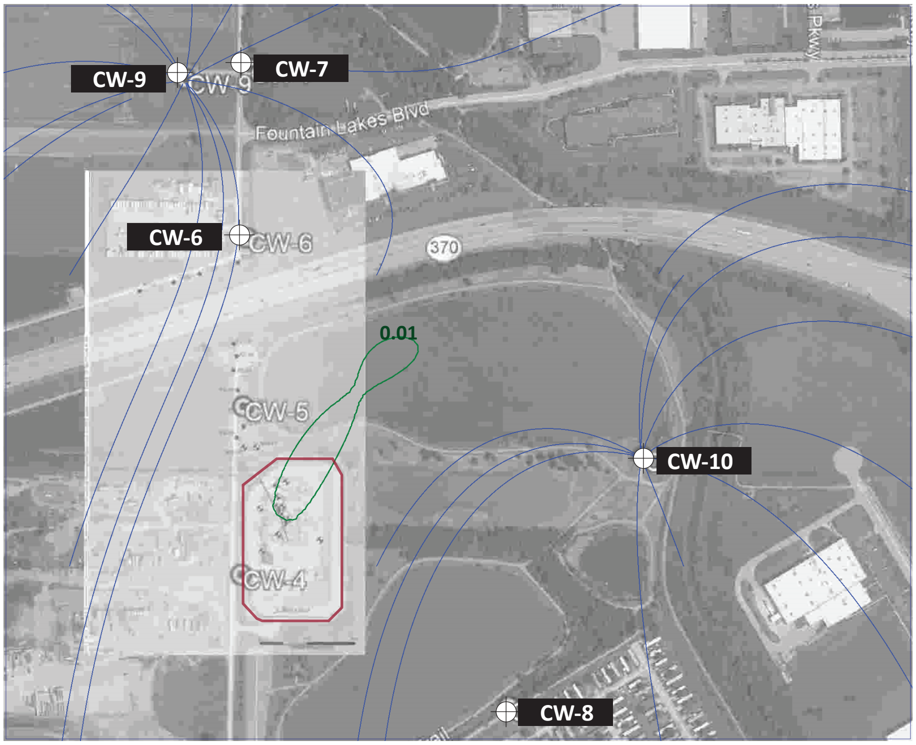
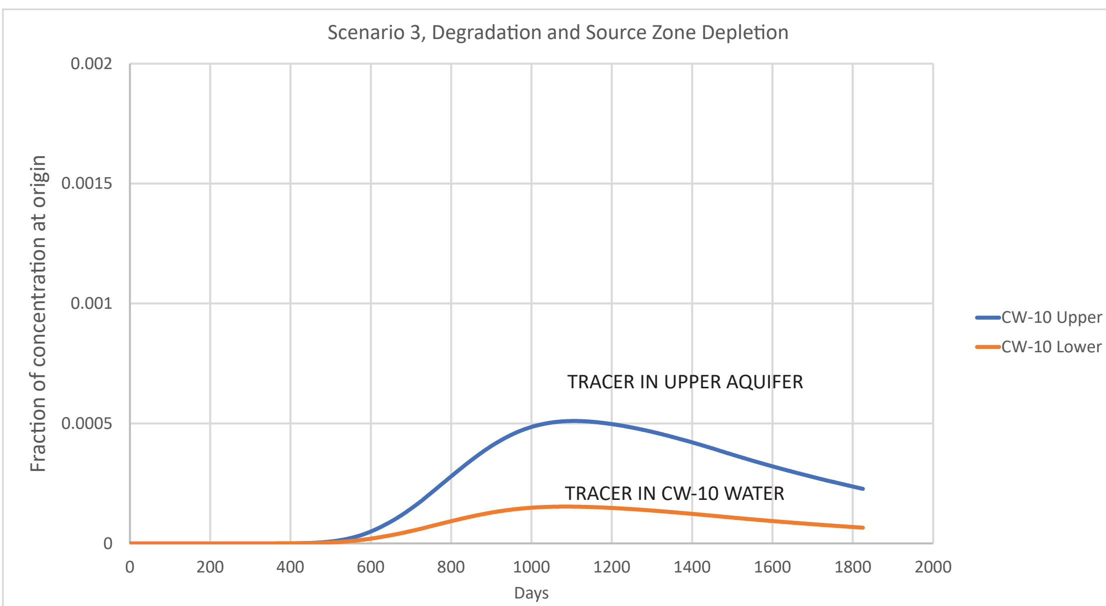
FIGURE 16

CW-6: 0 GPM
CW-7: 0 GPM
CW-8: 0 GPM
CW-9: 1,000 GPM
CW-10: 2,000 GPM





MAP EXPLAINATION

MODPATH PARTICLE TRACE
LENGTH = 5-YEAR TRAVEL TIME

0.3 CONTOURS: MT3D PASSIVE TRACER CONCENTRATION IN UPPER AQUIFER AFTER 5 YEARS (CONCENTRATION AT ORIGIN = 1.0)

MUNICIPAL GROUNDWATER EXTRACTION WELL

SITE

HALEY ALDRICH

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ST. CHARLES, MISSOURI

SCENARIO 3 MODEL RESULTS WITH DEGRADATION AND SOURCE ZONE DEPLETION

SEPTEMBER 2021

FIGURE 17